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INDIAN MUNITIONS BOARD

The Manufacture of Paint and Varnish in India

BY

N. BRODIE, B.Sc.,

(Chemist, Government Test House, Alipore)

Published by order of the Government of India

SOLD AT THE
OFFICE OF THE SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8 HASTINGS STREET, CALCUTTA

1919

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CSL 4

CONTENTS

PAGE.
I.—Introduction 1
II.—Vehicle and varnish materials 3
III.—Pigments 14
IV.—Manufacture of varnish 34
V.—Manufacture of paint 36

CSL 5

PREFACE

THIS memoir, like the "Review of the Trade in Indian Hides, Skins and Leather" and the "Notes on Wool" was prepared at the instance of Sir Thomas Holland, President, Indian Munitions Board, in order to draw the attention of the public to the existing state and the prospects of future development of certain Indian industries. It is believed that industrialists will appreciate the presentation in a single compact volume of all the available information regarding a particular industry.

Mr. N. Brodie, the author, who was on leave when the publication passed through the Press, desired to acknowledge the assistance of Mr. A. J. Gibson, Deputy Conservator of Forests, Punjab, who kindly undertook the revision of the sections dealing with turpentine, rosin and rosin oil, and of Dr. J. L. Simonsen, Chemical Adviser to the Indian Munitions Board, who made numerous suggestions and criticisms.

G. H. W. DAVIES,
Controller, Industrial Intelligence,
Indian Munitions Board.

SIMLA,
The 28th July 1919.

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INDIAN MUNITIONS BOARD

The Manufacture of Paint and Varnish in India

I.—INTRODUCTION.

The paint and varnish industry is a somewhat complex one, with many associated manufactures that are themselves undertakings of considerable importance. These associated manufactures are concerned with the production of paint materials, *i.e.* the separate ingredients of paint and varnish. The development of these manufactures in India, although perhaps greater than is generally known, is not very large and in the case of some materials, such as white lead, India is at present entirely dependent on foreign sources.

Mr. J. G. McIntosh, writing in 1915,* said :—" I would point out to British manufacturers, especially varnish manufacturers, that it is not Japan they have to fear as a competitor but India....... I confidently await the time when India will be sending us varnishes, both oil and spirit, from her own indigenous raw materials, linseed oil, alcohol, turpentine, shellac, dammer and other resins." Although it is difficult to agree altogether with this optimistic forecast, yet there is no doubt that the paint and varnish industries have not developed to the extent that the country's resources warrant and, up to the present, so far from competing with British manufacturers in European markets, India has imported much the greater part of her requirements of paints, paint materials and, more particularly, varnish.

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* Oil and Colour Trades Journal, Vol. XLVII, No. 849, page 292.

There are unfortunately no figures available to show the value of Indian manufactures of this kind. The imports during the last five years were valued as follows :—

TABLE 1.—*Imports of paint, varnish and paint materials (including linseed oil) into British India from 1913—1919.*

Year.	Value.
	£
1913-14	*607,686*
1914-15	*552,832*
1915-16	*584,671*
1916-17	*794,916*
1917-18	*662,896*
1918-19	*845,722*

The purpose of this brochure is to give some account of the present state of these industries in India and of their possible future development.

Ordinary paint consists of an intimate mixture of very finely divided solid particles, known as pigments, and a liquid, known as the vehicle. The vehicle is a mixture of a drying oil, usually linseed oil, and a volatile oil or "thinner," such as turpentine. When the paint is exposed to the air in a thin film, the thinner evaporates. Its presence is generally necessary because the mixture of pigments and linseed oil in the best proportions is too stiff to be applied properly. It also assists the penetrative power of paint that is applied to wood. The surface of the paint can be made more or less glossy by adjusting the proportion of the thinner. Paints with a large content of thinner dry with a flat surface because of the larger proportion of pigment in the remaining film.

Linseed oil, on exposure to the air, takes up oxygen and is gradually converted into an elastic solid substance. This acts as a cementing medium for the particles of pigment and produces a film which, reinforced by the pigment, is a protective covering of the surface to which it is applied.

The function of the pigment is to strengthen and support the paint film and to give it colour and opacity. Some pigments have a chemical

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effect on the oil, but in general they are inert and their function is mechanical. Nevertheless, pigments vary greatly in their value. Unfortunately the reasons for this difference are not well understood. Some pigments, such as white lead, and, more particularly, red lead, accelerate the drying of the linseed oil. Others, such as lamp black, have the opposite effect. In general, however, the drying of ordinary (raw) linseed oil is inconveniently slow. This defect is remedied by the addition of "driers," *i.e.* metallic compounds that accelerate the oxidation of the oil. These are best added to the oil, in which they are dissolved by the aid of heat, forming what is known as "boiled" oil (see page 5). Sometimes driers are added separately to paint.

In the case of varnish, the strengthening of the film given by linseed oil is attained by the incorporation with it of hard resins, usually copal. Varnish gives a hard, lustrous and transparent film and is used for the decoration of furniture, carriages, railway rolling stock, etc.

Paints made with a vehicle consisting largely of varnish instead of linseed oil are known as "enamel" paints. They give a hard coat with a better and more permanent gloss than can be obtained with oil only. They are largely used for decorative purposes.

Analyses quoted have been made in the Chemical Laboratory of the Government Test House, Alipore.

II.—VEHICLE AND VARNISH MATERIALS.

Linseed oil.

Of the drying oils used in paints and varnish, linseed oil is much the most important. It is obtained from the seed of the flax plant, known commercially as linseed. Linseed is grown principally in North and South America, Russia and India. In India, linseed is grown mostly in Bengal, the United Provinces, the Central Provinces and Bombay. The Indian production is extremely variable, but averages about 400,000 tons a year. Of this the larger amount is exported. At one time India was the chief linseed-producing country, furnishing about half the world's supply, but, as the total consumption has approximately trebled in the last twenty-five years, while the Indian production has increased but little, this is no longer the case. According to Fryer and Weston,* the propor-

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* Oils, Fats and Waxes.

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tions produced by different countries for the five years ending 1912 were :—

	Per-centage.
Argentine	31·3
Russia	23·7
United States	20·3
India	16·3
Canada	7·9

There are certain differences in the oils expressed from the seeds produced in different countries. This difference may be partially ascribed to the presence of impurities in the seeds, but, apart from this, there appear actually to be specific differences. In the trade, it is generally recognised that Baltic oil is the best, and it is specially prized for varnish making. There is some difference of opinion as to the relative merits of the other oils, but generally Indian oil is ranked next, followed by North American (*viz.*, that grown in the United States), and Argentine oil last. The Canadian linseed is said to be grown from Baltic seed and to yield oil of equally good quality.

Most commercial linseed oil is obtained by pressing the hot and moistened seed in hydraulic presses. Hot pressing gives a greater yield of oil than cold pressing, although it is doubtful whether the oil obtained is as good. Attempts have been made to perfect a practicable and economical method of cold pressing, but so far apparently without success. The oil can also be extracted by means of solvents, but it is said that oil obtained in this way is unsuitable for use in paint.

The freshly pressed oil is turbid and is usually clarified by " tanking," *i.e.* storing the oil in tanks, when the impurities gradually settle out. Even when apparently clear, some oils, though not, as a rule, Indian oils, throw down on heating a further deposit of " mucilage." Oil intended for use in the manufacture of varnish is sometimes tanked for some years.

The oil obtained by pressing and more or less prolonged tanking is the *raw* oil of commerce, and for many purposes it is used in this condition. More often, however, it undergoes a further treatment.

Oil required for making white paint is usually bleached, the commonest method being to treat it with a small quantity of sulphuric acid. The oil so obtained is known as *refined* oil. It is paler than *raw* oil but by no means colourless.

Boiled oil.

The greater amount of linseed oil is used in the form of *boiled* oil. There are many methods of "boiling" oil, but in modern practice it is usual to heat the oil to a comparatively low temperature, about 150°C or sometimes less : it is not actually boiled in the literal sense of the word. Sometimes air is blown through the hot oil. During the "boiling", driers are added ; these are usually lead and manganese compounds, sometimes one or the other but more often both, the lead being considerably in excess. The oxides, rosinates, linoleates and other salts of these metals are in use and also salts of cobalt and other metals. The colour and specific gravity and time of drying of the oil vary considerably according to the nature and amount of the driers, the time of heating, etc. Most makers sell a dark quick-drying oil as "double boiled", and a paler but slower drying oil as "pale boiled." A good *double boiled* oil usually dries (in India) in about six hours, *pale boiled* in about ten hours and *raw* oil in about three days, but there is naturally considerable variation. A good *boiled* oil is not only quick-drying, but gives a harder film than is the case with *raw* oil.

All the operations of linseed-oil manufacture mentioned are carried out in India. The oil sold by the best makers is of excellent quality, and is probably as good as the best foreign oil, and certainly better than much of that imported. The number of firms engaged in oil pressing is large, but they do not all reach the same standard. The *raw* oil is frequently poorly clarified, but in other respects is usually satisfactory. Refining is not done on a very large scale, and there appears at present to be little demand in India for this class of oil. Several firms produce *boiled* oil, but the quality is very variable. The best brands are quite satisfactory, but others are poor. Some oils do not dry rapidly and others, although quick drying, do not give good films. These poor results are probably due to ignorance of modern methods of oil boiling and also, in many cases, to the lack of adequate apparatus.

Adulteration.

Adulteration is, in spite of the present high prices, less common than it was a few years ago. *Raw* oil is seldom adulterated, but the adulteration of *boiled* oil is more frequent, other vegetable oils, fish oil, rosin, petroleum and various other substances being added. Imported *boiled* oil is frequently adulterated, and unfortunately, under the Customs regulations, a certain amount of adulteration is permitted, even though the oil be marked "genuine." This regulation is taken advantage of by European exporters and is obviously a most unfair form of competition. Moreover, the adulteration allowed is such as may entirely spoil the oil for paint making and, indeed, for any purpose for which linseed oil is likely to be used. A certain amount of oil is sold as adulterated (" reduced ") oil. In this case it generally contains a moderate amount of petroleum. Such oil gives very poor results, and it is difficult to see that it has any legitimate use, even in the case of the cheapest paints.

Previous to the war, considerable quantities of linseed oil were imported into India, mostly from the United Kingdom. Smaller quantities were exported, about 26,000 gallons going annually to the United Kingdom and very variable amounts to other countries, principally Australia and other British possessions. During the war, exports have increased and imports diminished, as shown in the following table :—

TABLE 2.—*Exports from and imports into India of linseed oil from 1910—1919.*

Year.	Exports.	Imports.
	Gallons.	Gallons.
1910-13 (average)	...	3,68,700
1913-14	1,02,360	4,39,482
1914-15	1,32,796	3,60,484
1915-16	2,80,850	2,67,687
1916-17	1,78,257	1,34,922
1917-18	5,57,663	62,995
1918-19	1,674,958	2,760

At first sight, it is not easy to see why it should be necessary to import linseed oil. Oil imported into India from the United Kingdom has possibly been pressed from Indian seed and, having paid freight both ways, one would think that its selling price would necessarily be higher than that of oil pressed in India. A difficulty arises, however, in India regarding the disposal of the " cake," *i.e.* the residue left after pressing the oil from the seed. This amounts to about seventy per cent. of the weight of the original seed, and there is at present comparatively little demand for it in India ; it therefore has to be exported, if it is to find a market. Were it possible to dispose of the cake in the country, the Indian manufacturer would presumably be able to export linseed oil, instead of the whole seed being exported as at present. But under present conditions, the Indian manufacturers are not able to sell linseed oil more cheaply than British manufacturers. Linseed oil is in fact generally cheaper in Great Britain than in India, and, even in India, in spite of the import duty, firms can usually offer oil pressed in England at a price but little higher than that of Indian oil. A contributory cause of the preference for imported oil is doubtless the poor results obtained with the inferior Indian *boiled* oils to which reference has been made.

Other drying oils.

Linseed oil is the most valuable oil used in the paint industry. It has a chemical composition not approached by that of any other oil, and for most purposes no adequate substitute is available. There are, however, other oils with drying properties, or which by suitable treatment may be made to dry, and these are sometimes useful for special purposes; but, whatever advantages they may have in particular cases, none has the lasting powers of linseed oil or, at least, none of the numerous claims that have been made to this effect has been substantiated. The price of linseed oil is generally low, but it is subject to violent fluctuations, and in times of high prices the substitution of other oils is common.

Tung oil.

Tung oil or Chinese wood oil is the most important of the drying oils other than linseed oil. It is expressed from the seeds of the *Aleurites cordata*. There are two varieties of this oil, Chinese and Japanese, but only the former appears to have come into use in the paint trade. The raw oil dries rapidly but gives a film quite unsuitable for paint making. When properly treated, however, it is said to become suitable for the manufacture of special paints. The main use of the oil is for the manufacture of varnishes, and for this purpose it is now largely used, especially in America. Accounts of the value of these varnishes vary, but they possess the property of being repellent to water in a remarkable degree. They are not, however, very durable.

In view of the increasing importance of this oil, attempts to grow the tree have been made in India, but it is too early yet to say whether these experiments will meet with success.*

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* The tree is cultivated here and there in Burma, but nowhere on a commercial scale and the nuts cannot at present be obtained in any quantity.

Fish oil.

Fish oil is obtained from the bodies of different species of fish and it is consequently very variable. It is a frequent and generally undesirable substitute for linseed oil, its chief recommendation being its cheapness. A small industry already exists on the West Coast of India.

Soya bean oil.

The soya bean is cultivated chiefly in the Far East, but it has also been grown in other countries, including India. The oil is chiefly used for soap making, but a little is used in the paint trade, mixed with linseed or tung oil. Attempts were made to use it more extensively when linseed oil was dear. It has poor drying properties and is of little importance in normal times.

Poppy seed oil.

The varieties of poppy used for oil pressing are grown in France, India and the near East. The oil is used in artists' paints, and sometimes for making white paints for interiors, as it is said to remain whiter than linseed oil. In other respects, it is inferior to linseed oil and is probably quite unsuitable for general painting.

Turpentine.

Turpentine is a very old ingredient in paints as a thinner, and in varnishes as a solvent. In the former case many paint mixers hold that the action is not solely mechanical. "Turpentine when exposed to the air absorbs oxygen, forming a substance of peroxide character, which acts as a particularly energetic oxidizing agent upon any oxidizible material which may be present; in the case of paints, the linseed oil." ("Outlines of Organic Chemistry" page 146, F. J. Moore, 1910.)

This accounts for the preference of many paint-makers for turpentine as against turpentine substitutes. "It has to be remembered that the oxidation of linseed oil is an autocatalytic process, that is to say, the reaction is hastened by the presence in the oil of some of the oxidized product. An application of the principle has made it possible to use a linseed oil which, instead of being boiled, has been partially oxidised at ordinary temperatures by agencies which do not affect the colour. A light, very transparent varnish is the result." ("Outlines of Organic Chemistry," page 146 F. J. Moore, 1910.)

This word of introduction will help to show how turpentine has attained the predominance it enjoys in the paint and varnish trade.

The "naval stores" industry, as the production of rosin and turpentine is known in America, originated in that country many years ago. To-day, the Southern and South-Western States of America produce about 80 per cent. of the world's output of turpentine, France coming

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next with about 12—15 per cent., and Spain, Germany, Greece and Russia taking the rest.

Turpentine is the liquid component of the oleo-resinous exudation or resin from certain pine trees. It is made by distilling the resin in copper stills in the presence of water or steam, the stills being heated either by direct fire heat, or, in more modern plants and especially in France, by steam. The residue in the still, when cool, forms the rosin or colophony of commerce.

The turpentines from the resins of various pines vary very largely in constitution and physical properties. American turpentine stands in a class by itself and is the standard turpentine of the world. This pre-eminence is rather a drawback in some respects, as consumers are prejudiced thereby and many a good merchantable turpentine has been rejected only because it did not possess the smell of the American product.

The manufacture of turpentine in India commenced as far back as 1895, but the first methods and apparatus employed were very crude and the products were barely merchantable; and consequently Indian turpentine got a bad name. Research was difficult, literature scanty, and expert investigators few.

The study offers exceptional difficulties, as turpentine is liable to molecular re-arrangement and to polymerization. About 1912, Indian workers got into touch with the research done by the "naval stores" section of the Science Faculty of the University of Bordeaux, research which has proved of the greatest value to turpentine producers in France, and, with this experience to profit by, Indian manufacture went ahead. The modern French steam distillation plant at the Punjab Forest Department factory at Jallo near Lahore commenced work in 1915, and a process has been evolved which produces an excellent first-grade turpentine and very good rosin. The plant is about to be doubled, while the United Provinces Forest Department are just completing a 3-unit plant of the same type near Bareilly. The errors of bad manufacturing processes and scrappy and uncertain research have been eliminated, and close touch with French methods in the future will ensure the production of the best turpentine which Indian pine resins are capable of yielding.

So far only the resin of *Pinus longifolia*, the "*chil*" or "*chir*" pine, has been dealt with commercially in India, mainly because of the accessibility of this pine-belt.

But the turpentine from the resins of *Pinus excelsa*, *Pinus khasya* and *Pinus merkusii* have been partially investigated (Puran Singh—Forest Bulletin No. 24 of 1913), and experiments on a commercial scale

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are now in hand. Preliminary experiments made at the Forest Research Institute, Dehra Dun, have indicated that the turpentine distilled from the gum-oleo-resin of *Boswellia serrata* is nearly, if not quite, equal in quality to American turpentine. Further experiments on the subject are in progress under Dr. Fowler at the Indian Institute of Science, Bangalore, and Mr. A. J. Turner in Bombay (see Ind. For. Rec. 1918, Vol. VI, Pt. VI).

The turpentine from *Pinus longifolia* resin is a complex mixture which has never been very completely investigated, nor have the conditions of the original distillation nor the origin and mode of collection of the resin samples been sufficiently detailed to be sure of the effect of these factors on the final analyses made. As the subject is one on the research programme of the chemical section of the Forest Research Institute, Dehra Dun, it is hoped that reliable data will soon be available.

Meanwhile the Jallo process has succeeded in putting an Indian turpentine on the market, which meets all requirements. It is used extensively by railways, the various public works departments, and incidentally by the medical department and many druggists. The Indian Quality I turpentine is a re-distilled turpentine which gives a 90 per cent. fraction boiling up to and under 170°C, with a small residue and a weak acid re-action (B. P. standard). Like all other turpentines it deteriorates on storage (see J. G. McIntosh—Manufacture of Varnishes, Volume III, page 110), or when exposed to air, heat and light.

The Quality I turpentine forms 75 per cent of the whole.

It is a moot point whether the Quality II and Quality III turpentines made should be placed on the market at all, as they can easily be converted into lamp black and profitably sold as such. (See page 33).

India uses about 220,000 gallons of turpentine a year.* In the financial year 1918-19 Indian production amounted to 145,000 gallons, and in 1919-20, it is estimated, the production will approximate to the pre-war demand.

The maximum possible output of Indian turpentine has recently been calculated at 120,000 cwts. or say 1,500,000 gallons a year, so an export trade is only a question of time and the finding of suitable markets.

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* *Note.*—This includes turpentine substitutes

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Turpentine substitutes.*

The increasingly high prices and the scarcity of turpentine have led to the employment of substitutes, which are usually petroleum fractions having a range of distillation approximating to that of turpentine. A good turpentine substitute should have a short range of distillation, as the presence of low-boiling oils leads to too low a flash point, with consequent danger of fire, and too rapid evaporation, while high-boiling oils are not sufficiently volatile. If this condition is satisfied, such a substitute not only adequately replaces turpentine in ordinary paint, but offers considerable advantages over it. Not only is it cheaper but it is not liable to oxidation and, therefore, does not deteriorate on storage, and leaves no residue on evaporation. This latter is a point of some importance, particularly in comparison with the poorer qualities of turpentine. Although the use of substitutes was first necessitated by a shortage of turpentine, the recognition of their advantages and the improvement of the quality of commercial products have led to their being valued for their own merits, and they are now very widely, perhaps universally, used by paint manufacturers.

Although petroleum is quite satisfactory as a solvent for linseed and other oils, it does not dissolve the hard varnish-making resins and, therefore, cannot be used by itself in the manufacture of varnish and of enamel paints. It is, however, found that it can be used mixed with turpentine for the purpose. Such mixtures are frequently used, but not, apparently, so widely as is a substitute for making ordinary oil paint. In view of the large amount of solvent necessary in the composition of a varnish and the deteriorating effect of the resinous residue left by turpentine on evaporation, the partial replacement of turpentine by a substitute offers obvious advantages.

Several firms in India manufacture petroleum substitutes and a certain amount is also imported from America. An increase in the demand for this important paint material may reasonably be expected, and there seems no reason why all that is required should not be supplied from local resources.

Coal tar distillates are also used in the paint industry. If free from low and high boiling fractions, naphthalene and tar acids, they are suitable substitutes for turpentine. They have the advantage of being good varnish solvents. These solvents have probably up to the present not been made in India, but the newly erected tar distilleries may in future produce them.

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* See for a general discussion on the use of turpentine substitutes the Oil and Colour trades, Journal, 1918, page 1294.

The more volatile coal-tar distillates, napthas and benzene, also find a use for special purposes. These also will no doubt be produced by Indian distilleries. Light petroleum distillates (benzine, etc.) are sometimes employed; these are already manufactured in Burma.

Resins.

The resins do not form part of the vehicle of an oil paint. They are, however, used in the manufacture of varnish, and therefore form part of the vehicle of enamel paints.

Copal.

Copal is a word used to cover a large variety of hard varnish resins. The copals are resins of very different origin, composition and properties. Some copals are fossil and others recent. The grading of copals is very complicated, but four divisions may broadly be distinguished, *viz.*, East African, West African, Kauri and Manilla. Generally speaking, the East African copals are the best, that shipped from Zanzibar having a particularly high reputation. The West African copals are also very valuable. The Asiatic copals, classed as Manilla, are found principally in the Philippines and Straits Settlements, while Kauri is found in New Zealand. Manilla and Kauri copals are very useful varnish resins, but not at all equal to those obtained from Africa. The difference between the various copals is principally a matter of hardness, the harder copals making the better varnish. No copal, or, at least, no copal suitable for making varnish, is known to occur in India. The copal used in the Indian varnish trade is mostly imported from Zanzibar and the Straits Settlements.

Dammar.*

Dammar is a resin exuded by several species of trees found in the East. The true white dammar comes from Singapore and is the produce of the Amboyna pine, *Dammara orientalis.* Somewhat similar dammars are rock dammar from *Hopea odorata* and *Hopea micrantha* which grow in Burma, whilst *sal* dammar from *Shorea robusta* is suitable for use in spirit varnishes. Amongst the other dammars found in India, to which attention may

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* Resins remaining after the removal of the essential oils from the oleo-resins derived from *Dipterocarpus indicus* and *Hardwickia pinnata* have been shown at the Indian Institute of Science, Bangalore, to be of considerable value for the manufacture of oil and spirit varnishes. (See "Oleo-resin from *Hardwickia pinnata* by K. Sitaram Iyer and J. J. Sudborough," Journal of the Indian Institute of Science, Vol. 2, Part III, pages 29-35 and "Oleo-resin from *Dipterocarpus indicus* by J. C. Mansukhani and J. J. Sudborough," *loc. cit.*, Vol. 2, part IV, pages 37-45.)

CSL

be directed, are the white dammar from *Vateria indica*, which is obtained in considerable quantities in Malabar and Kanara, and the black dammars from *Canarium strictum* (grown on the West Coast) and *Canarium reziniferum* (grown on the Assam and Khasi Hills).

Rosin.

Rosin or colophony, as stated in the section on turpentine, is the residue after driving off the turpentine by steam distilling the resin of various pines. As regards Indian manufacture, the progress attained in turpentine distillation was reflected in the quality of rosin made, and the Indian rosin now put on the market is as good as, if not superior, to American.

From 1907-1908 up to 1917-1918 Indian imports of rosin *plus* local manufacture have varied from 83,305 cwts. to 48,412 cwts. a year. In the financial year 1918-1919 the total Indian consumption was 51,910 cwts. of which Indian production accounted for 45,301 cwts. As industries such as soap factories, paper mills, paint and varnish concerns, etc., multiply and extend, the demand for rosin will increase. But Indian production also is increasing year by year, so that by the end of 1920 it is likely to exceed the highest year's supply in the past, and there may be more available than the country can absorb. Consequently the question of export is already receiving attention, and the Java, China, South African and United Kingdom markets for rosin are being exploited. A trade mark has been adopted for Indian rosin and turpentine, and it is hoped that these "Chir" brand products, made by Government and backed by the powerful guarantee of purity and unadulteration, will soon be well known in the East.

Rosin oil.

The destructive distillation of rosin gives a series of products of which pinolene, rosin oil, rosin gas and rosin pitch are the best known. So far manufacture has only been on a commercial experimental scale at Jallo, but steps have been taken to have a quantity of Indian rosin distilled in England by expert rosin oil manufacturers. If their reports are satisfactory, India will be in a position to supply other materials used by the paint and allied industries. Rosin oil finds a use in certain types of paint, but is not in general a desirable paint material. Rosin spirit is used to some extent as a substitute for turpentine.

Lac.

Lac is the exudation of the lac insect, which imbibes the resinous sap of several species of trees found in Asiatic countries. It is produced over wide areas in the centre of the Indian Peninsula, in Sind, Central Asia and Upper Burma. Lac comes on the market in various forms, the most important of which

MINISTRY OF CULTURE · GOVERNMENT OF INDIA
GSL

is shellac. The crude "stick" lac is washed, the product being known as "seed" lac. The "seed" lac is melted and drawn into the thin sheets which constitute "shellac." A little rosin is generally added to facilitate manipulation, or larger quantities, constituting adulteration, may be present.

III.—PIGMENTS.

The pigments used in the manufacture of paint are very numerous. They include both natural and artificial substances, and vary greatly in their composition and properties. Only the more important pigments are described here.

Inert pigments: Barytes.

Barytes is the natural form of barium sulphate. It is a mineral of wide distribution and is frequently found in association with lead ores. Deposits of barytes occur at several localities in India, of which the most important, as far as is at present known, are those near Betamcherla in the Kurnool district, Madras. A large deposit is said to have been discovered recently in Alwar State, Rajputana. Other localities deserving mention are Sleemanabad in the Jubbulpore district, Central Provinces; Alangayam, Salem district, Madras; Narravada, Nellore district, Madras; Khelat and Las Bela States, Baluchistan; Taung-gaung, Mandalay district, Burma; and the Bawdwin silver-lead mines.[*] The Indian deposits have only been worked recently, and until a few years ago all the barytes used was imported.

TABLE 3.—*Imports of barytes into India from 1913—1918.*

Year	Quantity.	Value.
	Cwt.	£
1913-14	4,986	*1,192*
1914-15	896	*205*
1915-16	1,008	*365*
1916-17	218	*150*
1917-18	892	*784*

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[*] Rec. G. S. I., XLVI, page 237 (1915).

MINISTRY OF CULTURE · GOVERNMENT OF INDIA

GSL

The occurrence of barytes in India is of some importance because of the very large use it finds in paint. This is due to its cheapness; its friability, which makes it comparatively easy to reduce to the required state of subdivision; its inertness, it being quite unaffected by anything with which it is likely to come into contact; its transparency and the small amount of oil which it absorbs in grinding, *viz.*, about eight per cent., which is less than is required for any other pigments, except red and white lead. These properties of barytes have led to its extensive use as an adulterant of more expensive pigments. It has also, however, a considerable legitimate use. It is now generally agreed that the presence of a certain proportion of barytes or other inert substance is an advantage in white paints, increasing their stability. This is very marked in the case of white lead paint which, particularly in damp hot climates, disintegrates, giving the effect known as "chalking." The admixture of barytes, of course, detracts from the opacity of white lead and other white pigments and, as too great a proportion decreases the protective power of the paint, only moderate amounts can advantageously be employed. Larger proportions are frequently present in coloured paints of which barytes often forms the "base." In this way it is possible to make use of pigments which in their pure state would be too expensive to use for general painting. With the very opaque pigments barytes can, owing to its transparency, often be mixed in largely preponderating amounts, with very little effect on the appearance of the finished paint. It is not uncommon to find such paints containing barytes to the extent of 90 per cent., or even more, of the total pigments.

Blanc fixe.

"Blanc fixe" or "permanent white" is the artificial form of barium sulphate. The name refers to its use in water-colour painting as a pigment. In oil, however, it has very little opacity and it cannot be used by itself. It is prepared by the precipitation of barium chloride by sulphuric acid. In its general properties it resembles barytes, but is finer and therefore suitable for some purposes for which barytes cannot be used. It is, however, much more expensive than barytes and is little used except for special purposes. It does not appear to have been successfully made in India, although its manufacture has been attempted. Under present conditions, the prospects of manufacture in India do not seem very promising. The demand is small and the high price of sulphuric acid offers a considerable difficulty. The barium chloride from which it is prepared would have to be made specially, whereas in Europe it is a waste product.

Gypsum.

Gypsum occurs naturally as hydrated calcium sulphate. It is found at a great number of localities in Northern India, especially in Rajputana, the Punjab, Sind and Baluchistan, and during the past 10 years there has been an annual outturn of 11,000 to 25,000 tons, chiefly from Bikanir and Jodhpur in Rajputana and to a less extent from the Jhelum district of the Punjab.* It may be used in paint in its hydrated form or after previous ignition to make it anhydrous. The former practice is to be condemned because gypsum is by no means insoluble in water. It is chiefly found in cheap dry colours, which are usually to be regarded with suspicion. Anhydrous calcium sulphate is rarely found in English paint, but it appears to be in common use in America, where it frequently takes the place of barytes. As in India there is an abundant supply of barytes, the use of calcium sulphate seems unnecessary and perhaps undesirable.

Whiting.

Whiting is finely ground chalk. It finds a certain use in ordinary paint, but is chiefly used in distemper, white-washing, etc. Ground to a stiff paste in linseed oil, it forms putty. Chalk suitable for making whiting appears to occur only in the South of England and the North of France. Most of the whiting of commerce comes from England. No chalk has yet been found in India.

Other inert pigments.

A few other pigments are sometimes used in paint in much the same way as barytes. Of these the most important are china clay, asbestine, which is a short-fibred form of asbestos, and the finely divided form of silica known as infusorial earth. China clay of high quality is obtainable at several localities in India, *e.g.*, in the Jubbulpore district, Central Provinces, and in the Raj Mahal Hills, but it has little to commend it as a pigment. It does not appear that asbestine has been so far found in India.

The iron oxide pigments.

The iron oxide colours are an interesting and important group of mostly natural pigments. Their cheapness, unalterability, high opacity and spreading power make them of great value to the manufacturer. The range of colours is very considerable, and we have yellow passing into various shades of brown, among the hydrated forms, and, in the anhydrous forms, a range from a fairly bright red to purplish shades, in addition to various brown anhydrous oxides. The causes of the variation in colour are not at all clear. A primary difference is naturally the state

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* Rec. G. S. I., XLVI, pages 275-276 (1915).

CSL

of hydration or otherwise of the mineral, but the presence of small quantities of ferrous oxide and of manganese and, in the case of anhydrous oxides, the temperatures to which they have been subjected, all affect the colour. Variations in opacity are also considerable, the true siennas and umbers being notably transparent.

The variety of iron oxide minerals has naturally led to some diversity of practice in different countries, manufacturers choosing their pigments in accordance with local conditions. It is possible therefore that, in India, a use will be found for pigments other than those described.

Red oxide.

The red oxides are a rather large class of natural and artificial pigments. The essential colouring matter is anhydrous ferric oxide, but the actual composition of the pigment is very variable. In the trade, various names, of which the principal are Venetian red and Indian red, are used but their application is not well defined. Generally, however, in English practice, the brighter and redder colours are known as Venetian red and the purplish colours as Indian red. The best natural oxide used in India is a bright variety from the Persian Gulf. In India itself, a purplish oxide comes from the Katni area in the Central Provinces, and various other oxides, usually of a brown colour, from other parts of India.

The following are analyses of three natural oxides :—

TABLE 4.—*Analyses of bright red, purple and brown oxide pigments.*

——	A*	B†	C‡
	Percentage.	Percentage.	Percentage.
Moisture	1·4	0·5	1·4
Loss on ignition	1·0	1·3	5·7
Silica	18·7	5·3	9·9
Ferric oxide	72·5	91·0	77·2
Manganese di-oxide	...	...	0·2
Alumina	2·8	1·7	5·7
Lime	0·7	trace	*Nil.*
Magnesia	2·5	*Nil*	trace
Sodium chloride	0·25	...	...
Total	**99·85**	**99·8**	**100·1**

* Bright red oxide from the Persian Gulf.

† Purple oxide (Olphert's oxide) from the Katni area, Central Provinces.

‡ Brown oxide, Indian (locality unknown).

The artificial red oxides, although not much used in India are of considerable importance in other countries. They have the advantage that they can be produced in a wide range of colours. The brighter shades are produced at comparatively low temperatures and the purple shades at high temperatures. Artificial oxides may be produced by roasting ferrous sulphate, when fuming sulphuric acid is obtained and a residue of ferric oxide left. They are also made from the waste liquors obtained in several industries, such as galvanising. The iron is precipitated by means of lime and the precipitate roasted. If the waste liquors contain sulphates, calcium sulphate is precipitated together with the iron hydroxide. Hence, artificial oxides frequently contain large quantities of calcium sulphate. Artificial red oxides are cheap and useful pigments, provided they are washed free of soluble salts, notably basic ferric sulphate. It does not appear that they have so far been made in India, but no doubt they will be in the future.

Yellow ochre.

Yellow ochre consists of hydrated ferric oxide in association with larger quantities of clay and silica. Deposits of varying composition and usefulness occur all over the world. In India, good ochres are found near Katni, where there are several mines in a fairly small area. Yellow ochres are worked in several of the Central Indian States (Panna, Baraunda, Gwalior and Sohawal), and are also found in laterite in various localities, in the Cretaceous rocks around Trichinopoly and among the Tertiary beds of the Myingyan district, Burma. Many other deposits, usually of very inferior ochres, have been suggested but, in view of the fact that some of the Katni mines producing quite good ochre appear to be unworked, it seems unnecessary to exploit inferior deposits. Table 5 below shows the analyses of ochres from three different mines in the Katni area.

Yellow ochres find a considerable use in paint, by themselves, mixed with barytes, and as stainers in making such paints as khaki, etc. Considerable quantities of ochres are imported but, in view of the good quality of Indian ochre, this should be unnecessary.

Red ochre.

Red ochre is similar in composition to yellow ochre except that the ferric oxide is present in the anhydrous form. It is used chiefly as a stainer. Somewhat similar pigments can be obtained by the ignition of yellow ochres. In India, red ochres are obtained in the Central Provinces, from Jauli in the Jubbulpore district and from the Gangai Zemindari in the Drug district and from laterite in various places. Table 6 shows two analyses of Indian red ochres.

TABLE 5.—*Analyses of ochres from three different mines in the Katni area.*

—	A	B	C
	Percentage.	Percentage.	Percentage.
Moisture	1·5	1·2	2·0
Loss on ignition	12·2	9·1	11·9
Silica	21·2	49·7	23·7
Ferric oxide	45·1	21·4	40·9
Alumina	19·8	18·0	21·0
Lime	trace	trace	0·1
Magnesia	trace	trace	trace
Total	**99·8**	**99·4**	**99·6**

TABLE 6.—*Analyses of two samples of red ochre.*

—	A*	B†
	Percentage.	Percentage.
Moisture	1·8	0·9
Loss on ignition	9·6	10·9
Silica	30·1	25·8
Ferric oxide	31·1	36·2
Alumina	27·2	24·0
Lime	0·1	0·6
Magnesia	trace	1·2
Total	**99·9**	**99·6**

* from the Katni area.
† of unknown origin but probably also from Katni.

Siennas ; umbers.

The true siennas appear to be found only in Italy. So-called siennas are obtained from America and probably elsewhere, but they are not altogether similar to the Italian varieties and must rather be regarded as substitutes for siennas. The best umber comes from Cyprus and is known as Turkey umber. Other umbers are found in Europe and America. None so far seems to be known in India. Various grades of ochre, umber and sienna could also probably be obtained from the manganese-ore quarries of the Vizagapatam district, Madras. Umbers and siennas, both "raw" and "burnt," are used as stainers. Their consumption is not very large.

White lead.

White lead is the oldest of the white pigments and still much the most important. It finds a large use not only in white paint but as the basis of many coloured paints. It is often used alone for making white paint, but modern practice is in favour of mixing it with other pigments, and the evidence of the advantage of doing so is quite conclusive. It has a marked tendency to "chalk," *i.e.* the surface of the paint becomes loose and can readily be rubbed off. This defect is particularly noticed in damp climates, and has been known to destroy the paint with great rapidity. In industrial neighbourhoods, sulphur compounds due to smoke attack the paint with formation of lead sulphide, which is black. Admixture with an inert pigment, such as barytes, or with zinc white, improves white lead in these respects.

TABLE 7.—*Imports of white lead into India from 1913—1919.*

Year.	Quantity.	Value.
	Cwt.	£
1913-14	21,747	*28,068*
1914-15	25,063	*37,784*
1915-16	18,320	*31,656*
1916-17	18,029	*46,019*
1917-18	10,853	*39,659*
1918-19	28,693	*113,702*

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Considerable attention has been given lately to the question of the practicability of making white lead in India.* The necessary lead could be obtained from Burma, and doubtless the acetic acid necessary for most of the important processes will in time be available. The present consumption of white lead is, compared with the average capacity of a white lead factory, small, but an increase in consumption is to be anticipated, and probably foreign markets will be found. Innumerable methods of making white lead have been proposed, and often tried experimentally, but few of them have proved successful in practice. The more important methods are :—

(1) The stack (or Dutch) process.
(2) The chamber process.
(3) The Carter process.
(4) The precipitation process.
(5) The Bischof process.
(6) The Rowley (or mild) process.

The stack process.

The stack is built up in a chamber of convenient size (*e.g.*, fifteen feet square by twenty feet high). A layer of spent tan is spread on the floor, and on this a layer of earthenware pots containing dilute (about three per cent) acetic acid. Lead cast in the form of gratings or other shape that will expose a large surface to the action of the acid vapours, etc., is placed on top of the pots or inside them, but resting on a ledge, so that it is not actually immersed in the acid. The layer of lead is then boarded over, and on the floor so formed is placed another layer of tan, followed by a layer of pots and lead, and so on until the chamber is filled. The chamber is then nearly completely closed up, leaving sufficient space for ventilation, and left for three or four months. The fermentation of the tan produces heat, which volatilises acetic acid and water, and at the same time generates carbon di-oxide. Under these conditions the lead is gradually converted into white lead. The corrosion probably proceeds much in the following way, although the actual reactions that occur in the stack are undoubtedly more complex than those indicated.

The acetic acid and oxygen of the air, in the presence of moisture and at a high temperature, convert the lead on the surface to basic lead acetate.

$$Pb+O+CH_3.CO_2H=CH_3.CO_2.\ Pb.\ OH$$ (Basic lead acetate.)

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* At Bangalore, a syndicate is now erecting an experimental plant to try a process of manufacture worked out at the Indian Institute of Science.

CSL

The basic acetate is decomposed by carbon di-oxide, giving the basic carbonate (white lead) and normal lead acetate.

$$6\,CH_3.CO_2.Pb.OH+2\,CO_2=\underbrace{Pb.(OH)_2,\,2Pb.CO_3}_{\text{White lead}}+\underbrace{3\,Pb(CH_3.\,CO_2)_2}_{\substack{\text{Normal lead}\\\text{acetate.}}}+2H_2O.$$

The normal lead acetate, water and oxygen attack more lead, reforming the basic acetate.

$$Pb\,(CH_3.\,CO_2)_2+O+H_2O+Pb=2\,CH_3.\,CO_2.\,Pb.\,OH$$

At the end of the time mentioned, the corroded lead is removed and crushed between rollers in a stream of water to remove the white lead from the unaltered metallic lead. The white lead then goes through an elaborate grinding process under water, finally being dried and, as a rule, ground in linseed oil for the market. Very often the white lead is ground in oil without previous drying, as under these conditions the oil displaces the water.

The chamber process.

The chamber process depends on the same principles as the stack process, but is more rapid, the corrosion taking place in about half the time required for the stack process. There are several varieties of the chamber process. As it is carried out in Eng'and, the chamber is built of brickwork and is fitted with a number of racks, on which thin strips of lead are hung. A stream of carbon di-oxide, produced by burning coke, air, and a mixture of steam and acetic acid vapour, is blown into the chambers. Corrosion takes place in a way similar to that of the stack process, and the subsequent treatment of the corroded lead is the same.

The Carter process.

The Carter process is still more rapid than the chamber process and takes about twelve days. The lead is first melted and then made to flow against a jet of high pressure steam, by which means it is obtained in the form of a coarse powder. The powder is fed into large wooden drums about twelve feet long and six feet in diameter, each drum holding some two tons of lead. The drums revolve slowly, once in ten minutes, on a horizontal axis. Dilute acetic acid and water are sprayed into the drum at intervals during the first few days, and a stream of carbon di-oxide and air maintained. The rotation of the drums causes the continual abrasion of the particles of lead, and this, together with the comparatively small particles used, accounts for the rapid corrosion.

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The precipitation process.

The original precipitation process was the French or Thenard process. Metallic lead was first converted into the oxide, litharge, by smelting in a reverberatory furnace. The litharge was digested with dilute acetic acid, the basic acetate being thus formed. The solution of basic acetate, after settling and filtering, was run into precipitation tanks and a stream of carbon di-oxide passed through it, white lead being then precipitated.

$$6\ CH_3.\ CO_2Pb.\ OH+2CO_2=Pb(OH)_2,2\ Pb.\ CO_3+3\ Pb.\ (CH_3\ CO_2)_2+2H_2O.$$

The solution after removal of the white lead contains most of the acetic acid as normal lead acetate, and is returned to the digestion tanks to dissolve more litharge. In this, its original form, the precipitation process is now probably not in operation. Its place, however, has been taken by modifications, of which the best known is the Matheson process. The Matheson process differs from the French process described, in the method of bringing the lead into solution as basic acetate. The molten lead is granulated by being run into water and is placed in tanks together with acetic acid, solution being obtained by passing in steam and water.

The Bischof process.

The Bischof process also starts with litharge. This is finely ground and subjected at a temperature of 300°C to the action of water gas, a mixture of hydrogen and carbon monoxide. The monoxide is reduced to a suboxide of indefinite composition. The suboxide is sprinkled with water and thoroughly agitated in the presence of air, when it takes up oxygen and water and passes into a basic hydroxide. The hydroxide is mixed with more water and discharged into vats containing a little lead acetate. The lead acetate is not theoretically essential and, in the somewhat similar Rowley process, is dispensed with. Its function is to shorten the time of reaction. A current of carbon di-oxide is passed into the vats and conversion into the white lead occurs. The process occupies about two days.

The Rowley process.

The Rowley (mild) process differs from other processes in that no soluble salts are formed at any stage. As in the Carter process, the lead is first converted into the form of a powder by blowing with steam. The fineness of the powder is, in this case, much greater than in the Carter process. The particles of lead are found to be coated with a film of suboxide and, on mixing with water and agitating with air in a manner somewhat similar to that of the Bischof process, a basic lead hydroxide is formed. The hydroxide is then freed from the ten or twenty per cent. of unaltered lead that remains and is passed into the carbonators, where it is again

CSL

agitated in a stream of carbon di-oxide, and in about thirty-six hours is transformed into white lead. As no soluble salts or other impurities are present, the white lead can be transferred direct to the drying pans.

Other processes.

Many other processes for the manufacture of white lead have been devised and several have been in operation on a commercial scale, but usually have been abandoned. Some of these processes are merely modifications of those that have been described. Others depend on different principles. Several processes depending on the intermediate formation of lead chloride and basic lead nitrate have not proved successful. Several electrolytic processes have been suggested and some of these may eventually be found to possess commercial possibilities. One such process consists in electrolysing a solution of sodium nitrate, the positive electrode being of lead. Lead nitrate is formed and, at the negative electrode, caustic soda. These two solutions are mixed and lead hydroxide is precipitated. This is converted into white lead by the action of carbon di-oxide or of sodium bicarbonate.

Comparison of different processes.

The stack process of making white lead is of great antiquity and, in spite of the progress made by other methods, still maintains the foremost place. No figures showing the quantities manufactured in England by the different processes are available, but the stack process greatly predominates. This is probably also the case in Continental Europe, although, before the war, large quantities of white lead were made by the chamber process in Germany. In the United States, where "quick" process white lead appears to be more favourably received than in other countries, the great majority of white lead is made by the stack process. According to C. D. Holley* the capacities of the different plants at work in 1909 were :—

	Tons per annum.
Stack process	114,000
Carter „	26,000
Matheson „	2,500
Rowley „	5,000

It is therefore evident that much of the greater part of the white lead produced is made by the stack process. This does not necessarily mean that it is the best process. It has the advantage of being the oldest established process, and the present plants will no doubt continue in

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* "The Lead and Zinc Pigments."

CSL

operation unless forced out of competition by the newer processes. Of new plants erected, it will probably be found that a large proportion, perhaps the majority, are arranged for the newer processes. It cannot be denied that the preference of consumers for stack process white lead has been in the past justified. Much white lead made by the newer processes was of inferior quality. It is easy to understand that a process capable of good results may, in its early history, be unsuccessful. All the processes of making white lead require for their successful operation a careful study of details, such as may easily at first not be fully understood. An attempt by quite inexperienced people to make white lead by the stack process would probably result in much worse failures than were experienced by the pioneers of other processes. It is matter for comment that several processes for making white lead have been tried and abandoned and subsequently resuscitated, usually in a modified form, with successful results. In some cases, processes successful in some countries have failed in others. The chamber process has not been successfully established in the United States, while the Carter process, which is successfully used in four factories there, appears to be unknown in Europe. If white lead is to be manufactured in India, the claims of the newer processes are worthy of serious consideration.

White leads made by the various well known processes show certain differences both chemical and physical. Theoretically, white lead is basic lead carbonate [$Pb (OH)_2 2Pb CO_3$), but in practice it may vary, in good white lead slightly, and in poor white lead considerably, from this composition. Abnormalities in composition are usually in the direction of an excess of combined carbonic acid, and some white leads contain large quantities of normal lead carbonate, the effect of which is detrimental. Apparently chamber white lead is more liable to this defect than stack process white lead, but it is by no means unknown in the latter. Carter process, Bischof process and Rowley process white leads approximate closely to the theoretical composition, but the former usually shows a slight excess of carbonate. It is sometimes stated that a precipitated white lead is high in carbonate, but this is not necessarily the case. A more serious defect, and one which is probably responsible for the disfavour into which precipitated white lead, at least that made by the older processes, is usually regarded, is the presence in it of lead acetate. Small quantities of lead acetate may be present in any of the white leads in the manufacture of which acetic acid is used. It is more apt to be found in precipitated white lead, apparently because in dilute solutions a highly basic and little soluble acetate is formed and precipi-

13404

CSL

tated together with the white lead. The presence of this acetate is highly detrimental as it leads to serious "chalking" of the white lead and a more rapid darkening and disintegration of the paint film.

Stack process white lead is apt to be coloured by stains from the tan, and the other processes therefore produce whiter white lead. The fineness of the different white leads varies considerably. The stack process and chamber process white leads are, in practice, the coarsest, the white lead from the Carter process being finer. The Bischof and Rowley processes are finer still, and precipitated white lead is the finest of all. The latter is found to absorb much more oil in grinding than do white leads made by other processes. The greater fineness of the newer white leads gives a greater spreading power, and perhaps some of the complaints of the inferior opacity of those products are due to this.

In view of the varying degrees of success attained by these processes in different countries and at different times, there is naturally some divergence of opinion as to the relative merits of their products. The newer processes are most largely represented in the United States, and the most detailed criticisms come from that country. It appears to be generally considered that the precipitated white lead is inferior to the others. Carter white lead seems to be regarded as nearly or quite equal to stack process white lead. Very favourable opinions have been expressed with regard to Rowley white lead. Its freedom from soluble salts and its fineness are points in its favour. The operations involved in its manufacture are said to be under complete control, which is not the case in the older processes, and it is also said to have a higher spreading power than stack process white lead, with equal opacity. Considering its comparatively recent origin, in 1903, the success of the process is striking.

In the cost of manufacture, the stack process is at a disadvantage. The large space required and the length of time occupied in corrosion, with consequent locking up of capital, lead to a high cost of production. The chamber process is better in these respects but is still expensive compared with other processes. The Carter process is much more rapid, although more acetic acid is used than is the case with the stack process. In all these processes a further expense is due to the necessity of using only the purest lead. In the precipitation process this is not necessary, and a further saving is in the cost of acetic acid, most of which is recovered. The process is rapid in operation and therefore offers considerable advantages. Unfortunately the defects to which the product is liable are such that it is unlikely successfully to compete with other white

15104

CSL

leads. The Bischof is a very rapid process and appears to offer considerable advantages. The Rowley process is probably the cheapest of all. No expense on account of acetic acid or other chemicals is incurred and the very pure lead essential to most processes is not required. The process is very rapid and economical of labour.

Lead poisoning.

The handling of lead compounds either in manufacture or use may result in the absorption of lead into the system, causing very serious symptoms and frequently death. Female workers are more affected than male, and the children of such women are unhealthy and seldom live long. In England the prevalence of this disease amongst white lead workers was at one time, and, to a considerable extent, still is, very serious. The problem has engaged the attention of several Royal Commissions, each of which has advocated restrictions in the manufacture or use of white lead. The precautions at present enforced in English factories have had a favourable effect in reducing mortality. The danger arising differs according to the process employed. It is greatest in the stack process, particularly in its crude forms, and probably least in the Rowley process, in which handling is reduced to a minimum. The handling of the dry white lead appears to be the most dangerous operation, and grinding in oil without previous drying offers great sanitary advantages. Immunity from lead poisoning depends largely on the workers themselves and the care with which they observe the regulations laid down for their protection. The introduction of the industry into India may be expected to be attended by grave danger to the operators, if all the precautions that experience has shown to be necessary are not strictly enforced. It is, therefore, to be hoped that such precautions will be insisted on from the very beginning of the industry.

Sublimed white lead.

The so-called sublimed white lead is essentially basic lead sulphate but contains a little zinc oxide, usually about 5 per cent. It is prepared directly from galena or natural lead sulphide, by heating the powdered ore in a blast furnace of a special type. The galena is volatilised and under the influence of the blast oxidised to the basic sulphate. The fume passes from the furnace through a series of condensers where the pigment is deposited. The zinc oxide is due to the presence of small quantities of zinc in the galena. The sublimed white lead contains no other impurities of any consequence. Sublimed white lead is a comparatively new pigment and has only come into prominence in recent years. When used by itself, it "chalks" more rapidly than white lead, although the "chalking" of the latter, when

CSL

it occurs, is more destructive to the paint film. Sublimed white lead, however, is not generally used by itself and, when mixed with other pigments, gives good results. There is no doubt that this pigment has, when used properly, very valuable properties and that it will in time be more widely used than it is at present. The only raw material required, galena, is found in Burma and, if this should prove of suitable quality, the cheapness and valuable properties of sublimed white lead make its manufacture in Burma or India a question worthy of consideration.

Zinc white.

The pigment properly known as zinc white (also called white zinc and Chinese white) is zinc oxide. The best qualities of zinc white are prepared by volatilising and oxidising metallic zinc. The fume of zinc oxide so formed is collected in large chambers. It is also made by roasting suitable zinc ores in a manner somewhat similar to that employed in the manufacture of sublimed white lead. These " direct " zinc oxides usually contain a small amount of lead sulphate. They are, therefore, inferior to the pure oxides. In some cases, however, this impurity is not a serious disadvantage.

The paint made from zinc oxide has a high spreading power and gives a hard smooth film which is inclined to crack with age. It is, therefore, not altogether suitable for use alone in outside painting, although in India often used in that way. It is, however, of great value when mixed with white lead. For inside painting, either by itself or mixed with lithopone, it is very suitable, as no darkening takes place. It is the most suitable pigment for making white enamel paint.

The manufacture of zinc white in India depends on supplies of metallic zinc or, for direct zinc white, of suitable zinc ores. It does not appear that the latter are available but doubtless when metallic zinc is produced successfully from Burmese resources (the Bawdwin mines, Northern Shan States), the question of manufacturing zinc white will be considered. Any project for making zinc white from imported zinc seems to offer little advantage.

Lithopone.

This pigment consists essentially of a mixture of barium sulphate and zinc sulphide, its value depending on the zinc sulphide content, which is as a rule about 30 per cent. It is prepared by mixing solutions of barium sulphide and zinc sulphate, and the resulting precipitate, consisting of a mixture of barium sulphate and zinc sulphide, is strongly heated, quenched in water and finely ground. The ignition results in the oxidation of a small quantity of zinc sulphide, so that the commercial pigment always contains a little zinc oxide.

Lithopone is a pigment of good opacity and is very useful for the painting of interiors. Used for outside painting, it darkens and cracks. It gives better results when mixed with zinc oxide. It cannot safely be mixed with white lead, owing to the possibility of the formation of the black lead sulphide. Some paint makers use lithopone in conjunction with special vehicles that are found to give good results with it. The raw materials for the manufacture of lithopone are barytes and zinc ore. The manufacture is complicated and it is not likely that the demand is sufficient to form an inducement to manufacturers in India, at least at present.

Litharge.

Although not strictly a pigment, litharge may be mentioned here. It is used in the preparation of boiled oil and as a drier in certain paints. It is also an intermediate product in the manufacture of red lead and in some processes of manufacturing white lead. It is made by the oxidation of metallic lead, usually in a reverberatory furnace. The monoxide so formed melts and is tapped off. In the case of that required for the manufacture of red lead, the operation is conducted at a lower temperature, so that the monoxide does not melt. In this case, it is usually known as massicot.

Litharge is made in India, but is frequently very impure. Besides such gross impurities as silica, etc., it usually contains considerable quantities of red lead, which makes it unsuitable for some work. There seems no reason why all the litharge required in India should not be made from Burma lead.

Red lead.

Red lead is manufactured by heating finely divided lead monoxide, (massicot), in an oxidising furnace. The mass is kept well stirred and by absorption of oxygen gradually passes into red lead. The conversion is usually not complete, and commercial red lead contains, as a rule, a rather large percentage of unaltered monoxide. This may, even in good brands, be as much as 25 per cent. of the whole. In poor brands it may be very much more. The monoxide detracts greatly from the value of the red lead and is the cause of its hardening when ground in oil. In recent years, improvements in manufacture have enabled red lead to be put on the market almost or quite free from monoxide, though little seems to have been used in India. It is claimed that, by careful attention to details, such red lead may be made by the ordinary process ; but it is probable that most of it is prepared by removing the excess of lead monoxide. One method of doing this is to digest the red lead in lead acetate solution, which removes the monoxide in the form of basic acetate. In addition to the monoxide, metallic lead is often found in traces and occasionally in larger quantities.

Red lead is used very largely for priming steel work, as it gives a hard undercoating of a highly protective nature. Its bright colour, particularly in the best qualities, has led to the suggestion that it should be used as a signal paint. The experiment seems worth trying, but not with the poorer qualities of red lead or even with many of those that prove satisfactory in general painting. It cannot be expected that a red lead containing much free monoxide will retain its colour satisfactorily.

Commercially, red lead is an important pigment as is shown by the following table of imports :—

TABLE 8.—*Imports of red lead into India from 1913—1919.*

Year.	Quantity.	Value.
	Cwt.	£
1913-14	43,827	*50,839*
1914-15	32,896	*38,348*
1915-16	28,900	*46,266*
1916-17	26,491	*65,695*
1917-18	25,733	*80,027*
1918-19	26,551	*95,009*

Several firms have attempted the manufacture of red lead in India, and in some cases successfully, the quality being about equal to that of red lead ordinarily imported. This is not to say that it is not capable of considerable improvement. As lead from Burma appears to be available, there seems no reason why all the red lead used in India should not be made in the country.

Orange lead.

Orange lead is a modification of red lead, produced by heating white lead in the colouring furnace. The white lead is decomposed by heat, giving the monoxide which is subsequently oxidised. The reason for the difference in the colour of red lead and orange lead is not known. It has probably not so far been made in India. The practicability of doing so naturally depends on progress in other directions.

CSL

Vermilion.

Vermilion is not in modern times as important a pigment as it was previously, its place being taken by imitations that are cheaper and better. Nevertheless, large quantities are still imported into India. Owing to the scarcity of organic colours for making imitation vermilion, its importance has increased during the war. Vermilion is largely made in China. Chemically, it is mercuric sulphide and is made by heating sulphur with mercury and subliming the product. There seems no likelihood of its being made in India.

Imitation vermilions.

Imitation vermilions have an extensive use in the painting of signals, brake-van-ends, etc., on railways, pillar boxes and for other purposes. Generally, such paints are made by tinting red lead and orange lead with organic lakes. The lakes that it is possible to use are very numerous and of greatly varying stability. All in time lose their colour on exposure to light, particularly under tropical conditions, and some lakes that are said to be suitable for European conditions are not satisfactory in India. Of the well known organic colours used for the purpose, alizarine lake is the most successful. Although British-made alizarine is obtainable, there seems to be a difficulty in making the lake, which is a calcium aluminium compound of alizarine.

Prussian blue.

Prussian blue is usually made by mixing ferrous sulphate with sodium or potassium ferrocyanide and oxidising the precipitate so obtained. The pigment is a mixture of several complex ferrocyanides and ferricyanides, but the principal constituent seems to be sodium (or potassium) ferric ferrocyanide. The composition is not constant and, therefore, the colour is rather variable. The best blues have a peculiar coppery lustre on their fractured surfaces. The variety known as Chinese blue shows this very well. Some of the poorer qualities have a muddy appearance and are of little use. Brunswick blue is a reduced colour made by precipitating Prussian blue on a base of barytes. Prussian blue gives a very rich, deep colour. It may be used by itself, but is, more usually, mixed with barytes as Brunswick blue. It is used to tint white pigments for the preparation of pale blue shades. One of the principal uses of Prussian blue is in the preparation of green paints. Prussian blue is made in India on a small scale.

Ultramarine.

The only blue pigment, besides Prussian blue, used to any great extent by paint makers is ultramarine. This is a complex body containing soda, alumina, silica

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and sulphur. Its exact composition is unknown. Its manufacture in India does not appear likely to be undertaken in the near future.

Chrome pigments.

The lead chromes are a series of pigments ranging in colour from pale yellow to red. The "middle chrome" is usually normal lead chromate, the paler shades containing more or less lead sulphate and the deeper more or less basic lead chromate. These colours are usually prepared by precipitation of lead nitrate or acetate with sodium or potassium dichromate, alone or mixed with sodium sulphate or with caustic soda, according to the shade desired. The paler shades are the most important; they are used for making yellow paints, and much more largely in the manufacture of greens. All varieties are made in India.

Zinc chrome is zinc chromate, and may be prepared by precipitating zinc sulphate with sodium chromate. It is sometimes used for making greens, but it suffers from the disadvantage of not being altogether insoluble in water. The addition of a small amount of zinc chromate to paints used for steel work is sometimes recommended, as it is supposed to have an effect in inhibiting the formation of rust. Even if this claim be substantiated, its use for making green paints is not likely to become general, since green paint is usually required for painting wood.

Chromium oxide is sometimes used as a green pigment. It is very expensive, but has the advantage of being permanent, and is the most satisfactory pigment to use in pale shades. It is said to be prepared by fusing sodium or potassium dichromate with boric acid. It is made in India.

The great majority of green pigments, however, under whatever name they are sold, are forms of Brunswick green, which is a mixture of barytes, Prussian blue and lead chromate, containing, almost invariably, more or less lead sulphate. By increasing the percentage of Prussian blue, the shade is deepened, pale, middle and deep shades being usually sold.

The colour is usually prepared by simultaneous precipitation of the pigments on a base of barytes. Owing to the presence of ferrous sulphate used to form the Prussian blue, lead sulphate is precipitated, brightening the shade a little. Brunswick green quite free from lead sulphate is a very dull colour. The colour thus prepared is the ordinary Brunswick green of commerce. By increasing the percentage of sulphate in the ingredients, much brighter greens can be made. The total range of colour obtainable is thus very wide.

Pigments of the Brunswick green type are sold under various names, of which the most familiar is "chrome green." Most manufacturers

GSL

draw a distinction between their Brunswick and chrome greens, *e.g.*, chrome green may contain more or less colour in proportion to the barytes or be of a different hue. Very often chrome greens are those containing a larger proportion of lead sulphate. Other green paints are made from zinc chromate, chromium oxide, etc., and sometimes organic dyes are used to get particular effects. All shades of lead chrome and of Brunswick, etc., green are made in India. Doubtless zinc chrome and zinc chrome greens could be made if necessary. Chromite, the natural source of all chromium compounds, is found in some quantity in Baluchistan, Singhbhum and Mysore.

Black pigments.

The great majority of the black pigments of commercial importance are forms of carbon. Lamp black, properly so called, is made by burning oils or other carbonaceous matter in a limited supply of air. The soot so formed is condensed and, if necessary, purified from any oil and tarry matter contained in it by igniting it in closed vessels. The black is collected in a series of several chambers, that from the chambers nearest to the burners being of the poorest quality. The better qualities are sometimes sold under the name of "vegetable black."

Carbon black is prepared in a somewhat similar manner by condensing the soot formed by the incomplete combustion of natural gas. As lamp black and carbon black are both nearly pure carbon and are produced in similar ways, it might naturally be thought their properties would be very similar. This, however, is not the case. Carbon black is a much deader black than lamp black; it has also several times the staining power of lamp black, but, when used for making grey paint, produces a brownish grey instead of the bluish shade that is generally desired. Lamp black, therefore, is used for making grey paint, while carbon black is to be preferred for making black paint. The use of carbon black is almost entirely confined to paint manufacturers, but lamp black is often bought by the general public. The majority of the commercial "lamp blacks" bought in the ordinary markets are, however, not true lamp blacks, but substitutes of lower staining power. Although, as the high staining power of lamp black may be an inconvenience to the ordinary user, there is doubtless a legitimate market for substitutes, the position cannot be considered very satisfactory, and such substitutes should be sold on their own merits.

By the calcination of bones is obtained a pigment consisting essentially of a mixture of carbon and calcium phosphate. This is properly known as bone black, but is usually sold under the names of ivory black or drop

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black, both misleading names. The name "drop black" is derived from the nearly obsolete practice of mixing this or other black pigment with gum water and forming it into drops.

None of these black pigments appears so far to have been made in India, although the manufacture of lamp black has been attempted. The suggestion of making lamp black has lately been revived and there seems every prospect of its being successfully carried out. There also seems no reason why bone black should not be made in India. There seems, however, at present, little prospect of making carbon black.

Lamp black and carbon black are noticeable for their fineness and lightness, the large amount of oil required to grind them, and their extraordinary staining power and opacity. The paints made from them last very well but dry poorly. These properties are doubtless largely interdependent. The poor drying properties of the paint are sometimes ascribed to the presence of resinous and oily matter but, although these may be present and still further affect the drying, there is no doubt that the defect is inherent. Black paints, therefore, contain comparatively large amounts of driers.

In addition to the amorphous forms of carbon, graphite is also used in paint and has, in conjunction with other pigments, very valuable properties. It will probably become in the future a very popular ingredient of preservative paint for steel. The best natural graphite comes from Ceylon, but it appears more usual to use the cheaper artificial graphite made at Niagara. This has the advantage of being extremely pure. There are deposits of graphite at several places in India, but the quality is usually inferior.

IV.—MANUFACTURE OF VARNISH.

Varnish manufacture.

There are several types of varnish of which the simplest are solutions of resins in volatile solvents, alcohol being mainly used. The most important of the spirit varnishes are those made from lac and sold as "shellac varnish," "French polish," etc. The lacquers are shellac varnishes tinted with soluble colours. Dammar varnish is usually a solution of dammar in turpentine. It is evident that all these varnishes can readily be made in India and there should be no need to import any of them.

Copal varnish.

Much the most important varnish is copal varnish, which is sold under such names as "oak," "carriage," "body," etc., varnish. Gold size is also a variety of copal varnish. The general method of making copal varnish consists first of "running" the gum, *i.e.* melting it. This operation is carried out in a cylindrical vessel set on wheels, so that it can be drawn on and off the fire. On melting the copal a certain amount of destructive distillation occurs, vapours being evolved and escaping. The loss sustained is considerable, but this treatment is a necessary preliminary, because the original resin does not under ordinary conditions remain dissolved in the oil and turpentine to be subsequently added. To the melted copal, previously heated, linseed oil is then added, well-settled raw oil being usually used in preference to boiled oil, which involves the addition of driers separately at a later stage. The mixture of oil and copal is heated until the constituents are thoroughly amalgamated, and is then allowed to cool, the turpentine or other volatile solvent being cautiously added in small quantities during cooling. The finished varnish is run into tanks, and allowed to mature for some months before being placed on the market. Owing to the variation in the different kinds of copal, varnishes of very different qualities are produced. The demand in India comes largely from the railways for use on coaches, and it is evident that, in the trying conditions in which it is used, only the best qualities of varnish can be expected to give satisfactory service. There is also a considerable demand for the cheaper varnishes, and these are already made in India. It would be desirable that the better qualities should also be made in the country but, although the general principle of varnish making is simple and well understood, the actual manipulation is highly specialised and can be learned only by prolonged practical experience. Any attempt to establish this industry in India would, therefore, necessitate the employment of highly skilled workmen, and such a venture would be likely to be successful only if carried out on a somewhat large scale. It seems doubtful whether the present demand is sufficient to offer an inducement to manufacturers. In other respects the prospects are good, the position as to raw materials being unusually favourable, while the plant required is of the simplest description.

Rosin varnishes.

In addition to the better quality varnishes made from copal, there is a large trade in rosin varnishes. These vary widely in their composition and usefulness, but none can stand prolonged exposure outside, and therefore all are of limited value. The simplest and worst kind of rosin varnish consists of a simple solution of rosin in a petroleum distillate, such as kerosene. Such a varnish has nothing to commend it, and its only point of interest is that it is (in India) often sold under the name of copal varnish. Rosin varnish made in a

MINISTRY OF CULTURE · GOVERNMENT OF INDIA

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way similar to that used for making copal varnish, *i.e.* in conjunction with oil, gives a soft and sticky film. To obviate this, the rosin is usually hardened by the addition of lime, with which rosin, being an acid substance, combines, forming calcium rosinate. Other hardening agents are sometimes employed. The rosinate varnishes give hard and glossy films, and are sometimes used to adulterate copal varnishes. This substitution is wholly illegitimate, since the rosinate varnishes are not permanent and in particular are badly attacked by water. These varnishes have, however, a legitimate use where permanence is not essential and quick drying paints may often consist largely of calcium rosinate. Considerable amounts of rosinate varnishes for such special purposes are made in India. The best rosin varnishes appear to be made by the use of tung oil replacing or partially replacing linseed oil. These varnishes are not, as far as is known, made in India.

Black varnishes.

By replacing a part of the copal in a copal varnish by asphaltum and operating in much the same way, the varnish known as "black japan" is made. Brunswick black is a somewhat similar varnish, but is usually made without copal, *i.e.* it consists of asphaltum, linseed oil and thinners only. Both these varnishes are made in India. A type of varnish is made by dissolving asphaltum in a suitable solvent, usually a petroleum distillate, and a somewhat similar product by dissolving pitch in a coal tar solvent. These solutions are sold under various fancy names, and are cheap and useful for painting work that comes into contact with water. Considerable quantities of pitch solutions are imported into India, and they have recently been made here on a small scale. With the extension of tar distilleries their output will doubtless be increased so as to supply all local demands.

V.—MANUFACTURE OF PAINT.

Paint manufacture.

The operations actually carried out in a paint works vary considerably according to local circumstances. The major allied industries (except varnish making) would not ordinarily be directly associated with a paint works, and manufactures, such as that of white lead, are usually separate undertakings. Minor manufactures are frequently included in the activities of a paint factory, but its essential operations are the treatment of raw natural pigments to convert them into a form suitable for paint making, the grinding of stiff paint, and the mixing of paint in its final form ready for application.

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The treatment of the raw natural pigments is a process of grinding and usually of levigating. The latter consists of floating off the lighter and therefore finer particles, such as are suitable for making paint, in a stream of water. Levigation may be combined with grinding, in which case the coarser particles as they sink are automatically re-ground, or it may be a separate operation. In some cases, where the whole of the crude material is not to be used in the paint, levigation may be used to affect a separation. Ochres, for example, may be freed from associated sand in this way. In such a case, it may be more economical to carry out the levigating and grinding, if the latter be necessary, at the mines, so that the manufacturer receives his pigments in a finished condition.

Stiff paint.

A large portion of the output of a paint factory is usually stiff paint. The reason for this is that, while it is difficult for users to grind dry pigments into finished paints, and indeed in most cases impossible for them to do so properly, the mixing of paint is a comparatively simple operation. The stiff paint can be stored satisfactorily, without the settling that takes place with a mixed paint, and the vehicle can, if necessary, be adjusted to the work to be undertaken. Even when the paint is sold ready mixed by the manufacturer, it is necessary to make a stiff paint in the first place, since experience shows that a good paint is not obtained by the direct mixing of the pigment with the amount of oil and thinners ultimately to be added. The stiff paint is generally, in the case of good paint, made with raw linseed oil. A certain proportion of boiled oil may be added in some cases. The amount of oil added varies very greatly with the pigment. For white lead about eight per cent. is necessary, and for barytes about the same. On the other hand, some pigments require more than their own weight of oil. The pigment, or more often mixture of pigments, after a preliminary mixing with the oil, is passed, usually several times, through a special paint mill. The usual type of paint mill consists essentially of three rollers running at different speeds, the paint passing between the first and second rollers and again between the second and third. The principal effect is a very thorough mixing of the pigment and oil. The finer subdivision of the pigment is a subsidiary point ; even if the pigment were originally as fine as is necessary in the finished paint, thorough grinding would still be necessary at this stage.

The mixing of the stiff paint with additional oil and thinners to make the finished paint is usually carried out on a large scale in a mixer consisting of a rotating pan, inside which vertical paddles with a more or less complex motion revolve. In most cases, the oil is boiled oil and the thinners perhaps usually a mixture of turpentine and turpentine substitute or sometimes the substitute only. A small quantity of paste driers is sometimes added.

Ordinary paint.

In the case of the raw materials required for the manufacture of ordinary paint, the position of India is very fortunate, comparing very favourably with that of the United Kingdom and perhaps of any other country except the United States. The vehicle materials, *viz.*, linseed oil, turpentine and turpentine substitute, are all obtainable from local resources, as are the more important of the natural pigments. Many of the artificial pigments are made in India, while others will probably also be in the future. The most important of the artificial pigments is white lead, and there is some prospect that the manufacture of this pigment from Burma lead will be undertaken, while the production of "sublimed white lead" direct from Burma galena should prove a profitable undertaking. Even, however, if these materials continue to be imported, the advantages of making most paints in India are still considerable. Many of them can be made entirely from the materials of India or neighbouring countries, while others contain only a comparatively small amount of imported material.

The actual making of paint, *viz.*, the grinding of pigment in oil and subsequent mixing with more oil and thinners to make the finished paint, is not a very difficult process, and there is, of course, no reason why it should not be carried out as well in India as in any other country, provided that the necessary machinery and skilled labour are available.

It is difficult to make a satisfactory estimate of the relative costs of imported and locally-made paint. A few paints consist of a single pigment ground in oil, but in most cases we have to deal with mixtures of pigments in which the proportions of the ingredients are at the discretion of manufacturers. The different proportions of pigments will in general require different amounts of oil to grind them, while in some cases, cheaper oils than linseed oil may be used, so that there is no satisfactory basis of comparison.

When the compositions of Indian-made and imported paints are identical, it is probable that, in most cases, the Indian paint can be produced at a price slightly cheaper than the imported paint. The actual difference in price will naturally vary considerably according to circumstances, but the advantage in favour of Indian-made paint will seldom be very large because of the small difference in price between Indian and imported linseed oil. In cases where considerable quantities of imported pigments are necessary, the advantage will naturally

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be less and, even if these pigments are to be made in India, it is doubtful whether the effect on the price of paint will at first be appreciable, because there is in such cases a general tendency to base the price of such materials on that of similar imported goods, and in the absence of sufficiently acute internal competition, this is likely to continue to be done.

The advantage to consumers of buying Indian paint does not depend entirely, or even chiefly, on the price that they have to pay. Other things being equal, it is an advantage that paint should be made in the country in which it is to be used. The accessibility of the manufacturer is often a matter of considerable importance, as is also his ability to study local conditions. The factor of most importance, however, is that of quality. To use anything but good paint is the poorest economy; it does not in fact always lead to a saving even in the first cost, since the spreading power of cheap paint is often very low. The inferior lasting qualities of poor paint make it ultimately very dear, when the cost of labour in re-painting is taken into consideration. Consumers will naturally want to know whether they can obtain Indian paint of good quality. The answer is that they can, if they are willing to pay the price and to take proper precautions in purchasing; the quality they obtain will ultimately depend on themselves.

It has been amply demonstrated that good paint can be produced in India, but it cannot be denied that there has been, up to the present, a feeling amongst many purchasers that they can only get satisfactory paint from Europe. The reason for this is no doubt in some cases prejudice. English and other imported paints are very frequently of extremely low quality and cannot be expected to give tolerable results, and there is no doubt at all that the users of these paints would have got much better results with some locally-made paints. Unfortunately, in other cases, there is only too good reason for this unfavourable opinion of Indian paints. Possibly tempted by the apparent simplicity of the operations of paint making, totally unqualified people have attempted to manufacture paint and also colours, boiled oil and even varnish. Although the manufacture of paint does not present any great technical difficulties, it is naturally necessary that the proper plant and skilled labour under experienced management should be available. The scarcity of good paint under war conditions has in many cases forced users to accept paint made in factories that are not adequately equipped, and the unfavourable impression thus created has undoubtedly reacted on those who proceed on proper lines.

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